

Firming Apple Slices

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THE widespread interest in the use of calcium salts for firming apples is an indication of the need for improving the texture and firmness of apple slices for pies and other uses. Over 10 million bushels of apples are canned or frozen each year, chiefly for pies. There are also large quantities of fresh apple slices sold for pie-baking. Additional quantities of apples, and varieties not now employed, might be used in pies if it were possible to improve the texture of the slices.

The restaurant pie trade requires that apple slices be firm enough to retain their shape when baked. The present practice is to select apple varieties on the basis of firmness rather than flavor. Many of the summer and early fall varieties have excellent flavor but are not used because they are too soft to be processed. Improved methods for firming would enable one to select varieties for processing on the basis of flavor instead of natural firmness.

Kertesz (1) has shown that calcium salts were effective in firming various plant tissues and suggested the practical application of the calcium treatment for canning and freezing fruits and vegetables. Calcium salts were used to firm apple slices prior to freezing and enable them to retain their natural structure and firmness upon defrosting.

Powers and Esselen (2) have developed several procedures for firming McIntosh apple slices. Dipping the slices in calcium chloride solution was quite effective in preventing fresh, canned or frozen slices from becoming excessively soft or mushy when baked into pies. They also firmed apple slices by cooking in dilute calcium chloride solution or by adding it to the sugar sirup covering the slices to be frozen.

The use of calcium to firm fruits preserved with sulfur dioxide has been described by Atkinson and Strachan (3), and by Woodruff and Cecil (4). Calcium salts also were effective in improving the firmness of olives (5).

Prior to the publication of the article by Powers and Esselen, this Laboratory began a study of methods for firming apples. At first, overripe McIntosh (in cold storage 6 months) were used. These apples did not respond to calcium but could be firmed by reacting with the enzyme pectase in the presence of calcium. Subsequently it was observed that mature or slightly immature apples could be firmed with calcium, a method much easier to use than the pectase-calcium treatment. The present re-

port is concerned with the response of different varieties to calcium chloride and reports studies on improved methods for applying the calcium treatment to fresh, canned, and frozen slices. Brief directions for use of the procedures discussed have been issued as an information sheet (6).

Materials and Methods

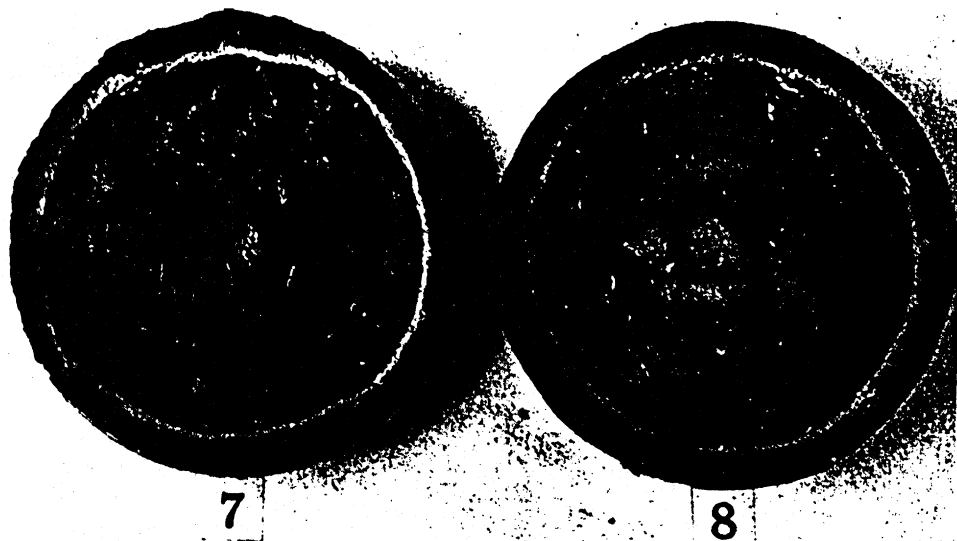
MOST of the apples used in this investigation were purchased from nearby orchards in Pennsylvania and New Jersey. A few Washington-grown Red Delicious and New England-grown McIntosh were obtained for comparison with the same varieties grown locally. The tests were made on both freshly harvested fruit and on that held in cold storage for four to eight months. For some of the studies on overripe fruit, the apples, after removal from cold storage, were allowed to ripen several days at room temperature. The apples were peeled, cored, and sliced into twelfths and the slices held in 1% sodium chloride brine until used.

The following vacuumizing and impregnation procedure was found to be very effective for applying various solutions to fresh slices, since it insured an even distribution of the treating solution throughout the tissues: Approximately 150 gms. of slices were placed in a pint Mason jar equipped with a rubber stopper and a Y tube connected to a vacuum line and a gauge. The slices were covered with the impregnating solution and submerged by means of a screen. A vacuum of 24 to 27 inches was applied for two or three minutes to remove air from the slices and then released, causing the solution to be forced into the interstices of the slices. The amount of solution absorbed, as determined by weighing the slices before and after impregnation, ranged from 6 per cent for freshly harvested apples to 30 or 40 per cent for fruit held several months in cold storage. Larger samples of slices were treated in the same manner in a vacuum desiccator instead of in a pint jar. The above impregnation and evacuation procedure was used in all the preliminary and varietal studies. Additional methods of applying calcium salts to apple slices were investigated as possible commercial procedures and are described under the appropriate headings.

Slices to be frozen were steam blanched and cooled in cold tap water before being packaged and frozen. They were packed without sugar in pint fiber cartons or gallon pails with friction tops and placed in a freezing cabinet

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Fig. 1—Rambo slices.
 No. 7, No treatment; firmness 1.
 No. 8, Deaerated and filled with
 0.1% calcium chloride solution,
 firmness 5.



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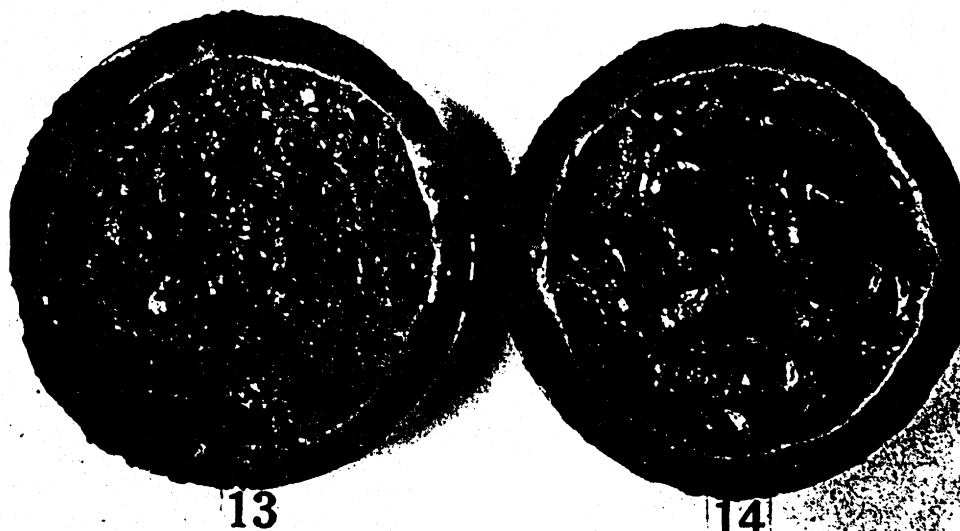
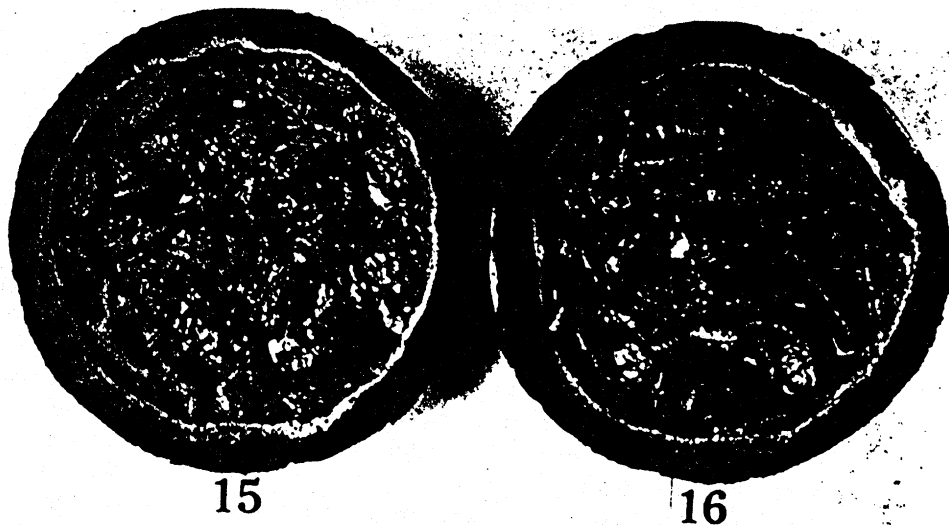


Fig. 2—Starr slices.
 No. 13, No treatment; firmness 0.
 No. 14, Deaerated and filled
 with 0.2% calcium chloride solu-
 tion; firmness 3.

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Fig. 3—Gravenstein slices.
 No. 15, No treatment; firmness 1.
 No. 16, Deaerated and filled
 with 0.3% calcium chloride solu-
 tion; firmness 3.



U.S.D.A. photo by M. C. Audsley.

at -20° C. The frozen slices were allowed to thaw at room temperature before being boiled or baked.

For canning, the slices were covered with water and heated to boiling. They were packed in pint jars or No. 2 enamel-lined cans and processed 20 minutes in a boiling water bath.

Canned slices were examined for firmness without being baked into pies. Small samples of fresh or frozen slices were cooked in boiling water for 20 minutes, cooled and examined for firmness. It was observed that a 20-minute cook softened the slices to about the same extent as occurred when they were baked in pies. Larger batches of slices were prepared for baking and made into pies at a commercial bakery.

Slices were treated with pectase by evacuation and impregnation and held at 25° C. for 1 hour prior to cooking. The pectase concentrate was prepared from tomatoes by extracting with 2% sodium chloride as described by Hills and Mottern (7). The crude extract was dialyzed until a precipitate appeared, the supernatant solution was decanted and the precipitate redissolved in a small volume of 2% sodium chloride solution. The pectase concentrate was diluted to an activity of 0.350 unit per ml. (7), which is about ten times the activity of the crude extract.

Slices were judged for firmness by noting the amount of pressure required to crush them between the thumb and index finger. Recorded scores are on a scale of 0 to 5, where 0 = mushy, 3 = optimum firmness, and 5 = tough. A few samples were tested with a Fellers-Clague (8) type penetrometer, but the readings were inconsistent and less dependable than the subjective scores.

Preliminary Studies

THE first experiments were made with McIntosh apples which had become overripe during 6 months' cold storage. These apples did not respond to calcium chloride. It was reasoned that if the slices were reacted with pectase, the enzyme which deesterifies pectin to products of greater calcium sensitivity, it might be possible to firm them in the presence of calcium salts. In order to promote pectase action it was necessary to add sufficient alkaline buffer, such as sodium acetate, to raise the pH of the apple tissue to 4.0 or above. The slices were adequately firmed by this mixture of pectase and calcium chloride in the presence of sodium acetate buffer, but were only slightly firmer than those treated with calcium chloride and sodium acetate alone.

During the summer these experiments were repeated with Yellow Transparent apples at various stages of maturity. The data presented in Table I show the difference in response of firm-ripe and of overripe Yellow Transparent apples to calcium chloride, and to mixtures of calcium chloride and tomato pectase. The firm-ripe slices required only a small amount of calcium to firm them adequately. Sodium acetate alone or in combination with calcium chloride made the slices tough, and it was impossible to determine whether the pectase caused any additional firming. The overripe slices did not respond to calcium chloride or to sodium acetate alone, but they did

TABLE I
Response of Firm-Ripe and Overripe Yellow Transparent Apples to Various Firming Treatments.

(All Solutions Applied by Evacuation and Impregnation and Slices Held 1 hr. at 25° C.)

Solution Used	pH*	Firmness Rating**
Firm-Ripe		
Water (Control)	3.2	2+
0.05% $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$	3.2	3
0.2 "	3.2	4
2.2% Sodium Acetate	4.0	5
+ 0.05% $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$	4.0	5+
+ " + 3.5 units Pectase	4.0	5+
Overripe		
Water (Control)	3.3	1
0.2% $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$	3.2	1
0.5 "	3.2	1
2.2% Sodium Acetate	4.3	1+
+ 0.05% $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$	4.2	4
+ " + 3.5 units Pectase	4.1	5

* pH of liquid surrounding cooked slices.

** Firmness rated on a scale of 0 to 5, where 0 = mushy or sauce consistency, 3 = optimum firmness, and 5 = tough.

to the combination of them, and the action of pectase gave some additional firming.

Data obtained on samples of overripe apples of other varieties followed the same general pattern of a slight or no response to calcium chloride, a definite response to sodium acetate plus calcium chloride, and a further increase in firmness when pectase was applied.

The effect of sodium acetate in increasing the effectiveness of the calcium ion was found to be due to the increased pH of the apple tissues and not due specifically to the acetate ion. Acetic acid produced no firming effect, whereas alkaline salts, such as disodium phosphate and sodium carbonate, gave the same increase in calcium response as observed for sodium acetate at equivalent pH values.

Other calcium salts may be substituted for the chloride. Calcium acetate was slightly more effective than calcium chloride, probably because it gave a slight increase in the pH of the tissues. Calcium gluconate and calcium chloride were equally effective when used in equivalent concentrations.

One should realize that high concentration of calcium chloride may impart an undesirable flavor to the slices. The amount required to affect the flavor is usually considerably greater than that needed to firm the slices. As calcium gluconate is almost tasteless, it may be used without affecting the flavor.

Varietal Studies

FOR routine tests on the response of different varieties to calcium chloride, the evacuation and impregnation procedure was preferred to the dipping method used by Powers and Esselen (2), since the latter method usually gives non-uniform firming.

Table II shows the response of 14 varieties of apples to various concentrations of calcium chloride.

Table II
Response of Different Varieties to Concentration of Calcium Chloride
(CaCl₂·2H₂O applied by evacuation and impregnation)

Variety	Maturity	Solution of CaCl ₂ ·2H ₂ O Used					Optimum
		0%	0.1%	0.2%	0.5%	1.0%	
Yellow Transparent	firm ripe	1	3	3		5	.1 to .2%
Williams Red	" "	2	3+	4+		4+	.1%
Rambo	slightly immature	2	4	5+		5+	less than .1%
Starr	" "	1+	3	4		5	.1%
Gravenstein	" "	1	2	3		5	.2
Wealthy	firm ripe	1+	2	3		3	.2
McIntosh (N. J.)	slightly immature	0	1	2	4	4+	about .3%
McIntosh (N. H.)	ripe	1	3	3+	4		.1
Smokehouse	immature	3	3	4+		5	0
Jonathan	firm ripe	2	4	4+	5		less than .1%
Red Del. (N. J.)	ripe	2+	4	5			less than .1%
Red Del. (Wash.)	firm ripe	3	3	4+	5		0
Golden Del.	ripe	1	3	3	3+		.1 to .2%
Stayman Winesap	slightly overripe	1+	3	3+	5		.1
Rome Beauty	ripe	2	3	3	4		.1 to .2%
York Imperial	"	2	3+	4	4		.1

The response varied somewhat with the variety and the stage of maturity, but in most instances 0.1 to 0.2 per cent was sufficient to give slices of optimum firmness. Higher concentrations usually gave slices which were too firm. There appears to be a difference in response of the McIntosh and Red Delicious apples grown in different areas, although this might have been due to slight differences in stage of ripeness when harvested.

Following the laboratory tests to determine the optimum calcium concentration, larger quantities both of firmed and of untreated slices were prepared from each variety and submitted to a commercial pie bakery. Pictures of a few of the pies are shown here to illustrate the contrast in appearance between calcium-firmed and untreated slices.

Commercial Procedures for Firming Apple Slices

STUDIES on the development of improved calcium-firming procedures for commercial usage had two principal objectives: (a) to apply calcium chloride to fresh, canned, or frozen slices with the least possible change in the present commercial methods of preparations, and (b) to produce as nearly as possible a uniformly firmed product.

Probably the ideal method for obtaining uniformly firmed slices would be to apply the calcium chloride solution by the evacuation and impregnation procedure described above. From a practical standpoint this has the disadvantage that it is a batch process and requires special equipment. For that reason it seemed desirable to study other possible procedures which could be used in plants engaged in the preparation of fresh, canned, or frozen apple slices.

Fresh Slices: Calcium salts may be applied to fresh apple slices either by the evacuation and impregnation method or by dipping. The use of the former method would be objectionable from the standpoint of Food and Drug regulations because it incorporates water in the slices and thus constitutes adulteration of the product. This objection would not necessarily apply to canned or frozen slices. In fact, it is common practice to deaerate

and impregnate apple slices with water prior to canning (9, 10, 11), and there are at least two commercial processes for deaerating and impregnating slices to be frozen. (12, 13).

The principal difficulty encountered in firming fresh slices by dipping in calcium chloride solution is the problem of inadequate penetration. Slices cooked soon after being dipped usually show case-hardening; that is, the slices are toughened on the surface but are still soft in the interior. Case-hardening is most pronounced with soft apples because the contrast between the toughened surface and the untreated tissues near the center of the slices is most noticeable.

Studies on fresh slices were aimed at minimizing non-uniform firming. It was observed that if dipped slices were held for several hours before being cooked, the calcium chloride diffused deeper into the tissues and reduced the severity of case-hardening. These data are shown in Table III.

Holding periods of three hours or longer resulted in improved texture and firmness of the slices, although uniform firming was not obtained even after 18 hours. Fresh slices to be held for several hours prior to baking should be protected against undue discoloration from exposure to air.

Canned Slices: In commercial practice, slices to be canned are usually deaerated by evacuation and impregnation (9, 10, 11). This procedure not only improves the drained weight of the pack, but tends to produce firmer

Table III
Effect of Holding Time on Penetration of Calcium Chloride
Into Fresh Apple Slices
(McIntosh apples dipped 10 min. in 1% CaCl₂,
then held for specified time before being cooked).

Holding Period, in Hours, Between Dip- ping and Cooking	Firmness Rating	Remarks
0	2	severe case-hardening
1	2	"
2	2	"
3	3	"
4	3	case hardening improved
6	3	"
18	3+	slight case-hardening

Fig. 4—McIntosh slices.
No. 25, No treatment; firmness 1.
No. 26, Deaerated and filled
with 0.5% calcium chloride solu-
tion; firmness 4.



U.S.D.A. photo by M. C. Audsley.

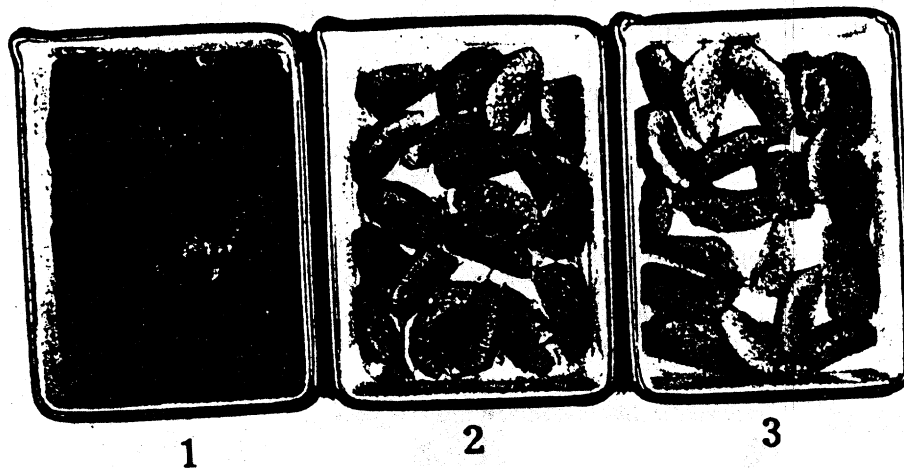


Fig. 5—Canned Starr slices after 7
months' storage.
No. 1, No treatment.
No. 2, Cooked in 0.1% calcium
chloride solution before canning.
No. 3, Dipped 1 hr. in 1.0%
calcium chloride solution before
canning.

U.S.D.A. photo by M. C. Audsley.

slices by preventing disintegration due to thermal expansion of air in the tissues.

Table IV shows the results of a series of canning experiments in which calcium chloride was applied to canned apples in various ways. The concentration of calcium chloride required to firm the slices varied with the method of treatment. For example, when slices were firmed by dipping it required a stronger calcium chloride solution than when the slices were firmed by impregnation or by adding the solution to the can. The samples were examined at intervals over a 7 months' storage period and evaluated for firmness and uniformity. The Starr variety used in this experiment is too soft to be processed without some firming treatment. The slices which were evacuated and filled with distilled water were definitely better than the slices which were not deaerated. Slices filled with water and then cooked and packed in dilute calcium chloride solution were much firmer and showed less case-hardening than slices which were dipped or cooked in calcium chloride solution without being deaerated. The degree of case-hardening tended to decrease during storage, and after 3 months all the samples were much improved in this respect. The evacuation and impregnation procedure produced the best product from the standpoint of appearance and uniformity of texture. Procedure No. 5 (Table IV) would probably be the best one for large-scale commercial

usage because it would require the least change in the present methods of canning. The product showed slight case-hardening at first but after 3 months' storage the slices were uniform in firmness.

Figures 5 and 6 show pictures of the canned slices after 7 months' storage. The numbers of the trays correspond to the numbers of the samples in Table IV. Figure 7 shows a side view and a cross-section of the canned slices in trays No. 3 and No. 6. The three slices on the left were firmed by dipping in 1.0 per cent calcium chloride solution. The soft interior portion of the cross-sectioned dipped slice was removed with a blunt glass probe to indicate the depth of penetration of calcium chloride during 7 months' storage. The three slices on the right were evacuated and impregnated with 0.2 per cent calcium chloride. The impregnated slices contained no soft areas removable by the glass probe and were uniform in firmness, as shown by the cross-section on the extreme right.

One large processing plant in Canada prepared calcium-firmed canned apples during the past season, utilizing fruit which otherwise would have been too soft for processing. Several apple canning plants in this country plan to use the calcium firming treatment during the coming season. It will enable them to begin their canning season several weeks earlier than usual by canning some of the late summer or early fall varieties which are not util-

Table IV
Effect of Method of Applying Calcium Chloride
on Firmness of Canned Apple Slices
(Starr Variety Apples, Fully Ripe)

No.	Treatment	Firmness of Cooked Slices at			
		1 day	1 Mo.	3 Mo.	7 Mo.
1.	Control—no treatment	0	0	0	0
2.	Cooked in 0.1% CaCl ₂	1+ (CH)*	2+ (ch)**	2+ (ch)	2 (ch)
3.	Dipped 1 hr. in 1% CaCl ₂	2(CH)	2(CH)	2(ch)	2+ (ch)
4.	Filled with distilled H ₂ O	1	1	1	1
5.	Filled with H ₂ O, cooked and packed in 0.1% CaCl ₂	3(ch)	4(ch)	4+	4+
6.	Filled with 0.2% CaCl ₂	4	4	4	4

* CH means severe case-hardening.

** ch refers to slight case-hardening.

ized for canning at present. It will also enable canning plants to maintain a uniform product with respect to firmness throughout the entire canning season.

Frozen slices: The present study was limited to steam-blanching frozen slices. It is beyond the scope of this paper to discuss other procedures for preventing discoloration of frozen slices except to mention that it should be relatively easy to incorporate calcium firming with either the sulfite or the ascorbic acid treatments. In fact, a combination sulfite-calcium chloride dip has been used successfully with apple slices in the New England area (14).

There are several possible methods of applying calcium chloride in the preparation of blanched frozen slices. Powers and Esselen (2) used three different procedures: (a) dipping in calcium chloride prior to blanching; (b)

blanching in boiling water containing calcium chloride, and (c) covering the blanched slices with a sirup containing calcium chloride. We have studied these procedures and have used two additional ones: (d) evacuating and impregnating with calcium chloride solution before blanching, and (e) dipping in calcium chloride solution following steam blanching. Firm-ripe Yellow Transparent apples were used in comparing the 5 methods for applying calcium chloride prior to freezing. Methods (d) and (e) gave the most uniformly firmed slices, although method (c) was also satisfactory. Slices dipped or blanched in calcium solution showed case-hardening, although it was not so severe as encountered with dipped slices which were cooked immediately. One is tempted to conclude that freezing and thawing facilitate the penetration of calcium salts in some manner.

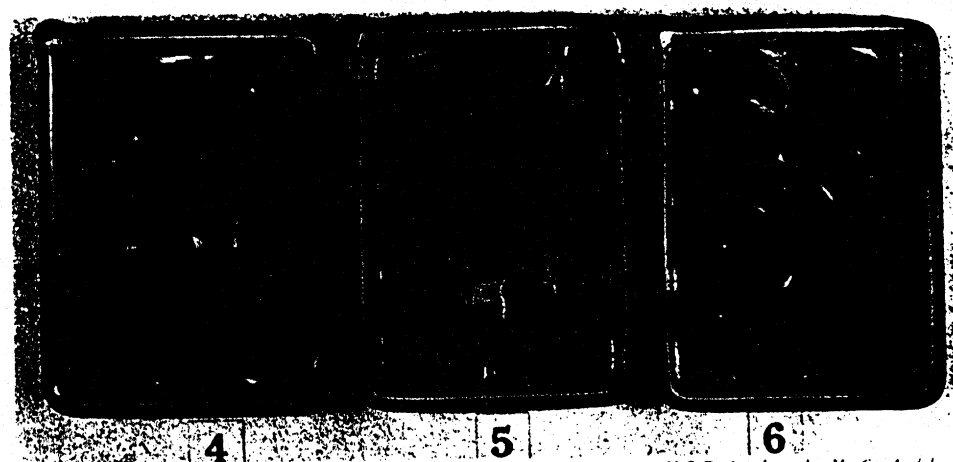


Fig. 6—Canned Starr slices after 7 months' Storage.

No. 4, Deaerated and filled with distilled water.

No. 5, Deaerated and filled with distilled water, cooked and packed in 0.1% calcium chloride solution.

No. 6, Deaerated and filled with 0.2% calcium chloride solution.

U.S.D.A. photo by M. C. Audley.

Fig. 7—Canned Starr slices after 7 months' Storage.

Left: Slices dipped in 1.0% calcium chloride before canning. Cross section with soft tissues partly removed to show depth of firming.

Right: Slices deaerated and filled with 0.2% calcium chloride solution.



U.S.D.A. photo by M. C. Audley.

From the standpoint of ease of application and uniformity of product, we prefer method (c), since it involves little if any change in some of the present methods. In most processes, the steam-blanching slices are cooled by dipping or spraying with cold water. It would be relatively simple to add calcium chloride to the cooling solution, although from the standpoint of economy it might be desirable to recool and recirculate the cooling solution as is now done at some plants.

Table V shows the effect of various concentrations of calcium chloride added to the cooling solution. The slices were steam blanching 90 seconds and dipped 5 minutes in cold tap water containing various concentrations of added calcium chloride. The calcium content of the tap water was equivalent to about 0.007 per cent $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$.

Table V
Firming Steam-Blanched McIntosh Slices By Cooling In Dilute Calcium Chloride Solution Prior to Freezing
(Slices blanched 90 sec., dipped 5 min. in $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ Soln.)

% $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ in Cooling Soln.	Consistency of Cooked Slices	
	Firmness Rating	Remarks
None (Control)	1	very soft
0.2	3	optimum firmness
0.5	3	" "
1.0	3	" "
2.0	4	too firm

The exact concentration of calcium chloride added was not critical, satisfactory results being obtained with concentrations ranging from 0.2 to 1.0 per cent. In another set of experiments the time of contact with 1.0 per cent calcium chloride solution was varied from 2 minutes to 30 minutes with no appreciable difference in the degree of firming. While the time of contact with the cooling solution is not critical, it should be long enough to remove the excess heat from the slices. On cooling, the slices actually increase in weight by 2 or 3 per cent, indicating that some of the solution may be picked up by imbibition. Since this amount of calcium solution alone would hardly be sufficient to firm the slices, it is probable that additional calcium is picked up by diffusion. The slices firmed by this procedure were uniform in texture and showed no case-hardening when thawed and cooked.

Food Regulations

ANY processor contemplating the preparation of calcium-firmed apple slices should make certain that his product would comply with the general provisions of the food and drug laws. Assuming that the calcium salt used was of a suitable degree of purity, there would probably be no fundamental objection to its use provided it was properly declared on the label.

Several years ago the Food and Drug Administration held hearings on the use of calcium chloride for firming canned tomatoes, and the standard of identity of this product was modified to permit the addition of 0.07 per cent (calculated as anhydrous calcium chloride and based on the total weight of the pack). The quantity of calcium chloride required to firm apple slices is usually less than this amount when calculated on the same basis. Since

there is no standard of identity for fresh, canned, or frozen apple slices, there are no specific requirements to meet, and only the general provisions of the law regarding adulteration and proper labeling would apply.

Summary

STUDIES are reported that confirm previous reports on the effectiveness of calcium chloride for firming fresh, canned, or frozen apple slices. Based on results with 14 summer and fall varieties, it is concluded that all varieties of apples may be firmed with calcium chloride. Other soluble calcium salts may be used in place of the chloride.

As apples ripen, they require more calcium to firm them. Overripe apples could not be firmed adequately with calcium chloride alone. A combination of calcium salt and sodium acetate gave firm slices, and the enzyme pectase gave some additional firming.

The chief difficulty in applying calcium to apple slices is inadequate penetration. The presence of air in apple slices interferes with rapid penetration of calcium ions into the interior of the slices. Slices dipped in calcium chloride solution were firmed only on the surface. Studies on canned dipped slices indicated that the calcium migrated slowly toward the center of the slices during storage.

Several improved procedures were developed for firming canned or frozen apple slices which require only slight changes in the usual methods of processing. The concentration of calcium chloride required to firm apple slices will depend on the variety and stage of maturity of the apple and the method of application, and should be determined by a series of small-size tests.

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